Analysis of forces developed during mechanical preparation of extracted teeth using RaCe rotary instruments and ProFiles

F. M. da Silva, C. Kobayashi & H. Suda

Pulp Biology and Endodontics, Department of Restorative Sciences, Graduate School, Tokyo Medical and Dental University, Tokyo, Japan

Abstract

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Aim To compare the torque and load during instrumentation with ProFile and RaCe nickel-titanium rotary instruments.

Methodology Thirty human incisor roots 12 mm in length were embedded in epoxy resin, and divided into three groups of 10 specimens each. Instruments employed in each group were as follows: RaCe .02 Step Back Files in group 1; RaCe .04 Step Back Files in group 2; and .04 ProFiles in group 3. Two load cells, whose outputs were connected to a digital oscilloscope, recorded torque and vertical load. Data were analysed by one-way ANOVA.

Results Torque values were statistically different between groups 1 and 3, and between groups 2 and 3 (torque was higher in group 3 than in groups 1 and 2). Vertical loads were statistically higher in group 3 than in groups 1 and 2.

Conclusions Torsional and vertical forces can be evaluated during instrumentation of straight root canals using the device and methods described in this study. When the step-back technique was employed, torque and vertical load obtained with RaCe instruments were lower than that obtained with ProFiles.

Keywords: nickel-titanium, rotary instruments, torque, vertical load.

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Introduction

The low modulus of elasticity of nickel-titanium instruments permits maintenance of the original canal shape and minimizes iatrogenic errors such as ledging, zipping and canal transportation (Glosson *et al.* 1995, Thompson & Dummer 1997). In addition, when compared with stainless steel instruments, Ni-Ti instruments demonstrate a superior resistance to fracture (Schäfer 1997). When Ni-Ti files are used with a rotary device, instrumentation time is significantly shorter than with hand files (Gambarini 2001a), resulting in less fatigue for both the operator and the patient.

However, Ni-Ti instruments may also exhibit an increased incidence of breakage for several reasons, including cyclic fatigue (Gambarini 2001b), instrument design and technique of instrumentation (Bryant *et al.* 1998), lack of operator experience (Barbakow & Lutz 1997, Mandel *et al.* 1999, Yared *et al.* 2000), degree of curvature of the canal (Pruett *et al.* 1997), torque generated (Kobayashi *et al.* 1997, Sattapan *et al.* 2000) and vertical load causing increase in torque (Kobayashi *et al.* 1997).

As it is believed that the torque control mechanism of the handpiece is effective in minimizing file breakage, a

Correspondence: Fabíola Mendonça da Silva, Pulp Biology and Endodontics, Department of Restorative Sciences, Graduate School, Tokyo Medical and Dental University, 1-5-45 Yushima, Bunkyo-ku, Tokyo 113-8548, Japan (Tel./fax: 81 3 5803 5494; e-mail: fabiendo@tmd.ac.jp).

number of handpieces incorporating such a mechanism have been developed (Kobayashi *et al.* 1997, Gambarini 2001b).

Recently, the RaCe (FKG Dentaire, La Chaux-de-Fonds, Switzerland) Ni-Ti rotary instruments have become available. The instrument has a triangular cross-sectional shape along its length with helical and undulated edges. This characteristic may allow the instrument to rotate inside the canal without having continuous contact with the walls, rather contact may be present only at specific points. According to the manufacturer, the alternating cutting edges reduce the phenomena of self-threading and frictional forces, and therefore minimizes risk of instrument breakage.

The purpose of this study was to compare torque and vertical load obtained during instrumentation of extracted teeth with ProFile and RaCe nickel-titanium rotary instruments.

Materials and methods

Tooth preparation

Thirty human maxillary and mandibular central and lateral incisors were used. The teeth were decoronated at the cemento-enamel junction and the roots were adjusted to a 12 mm length. The root apex was covered with red wax, to avoid penetration of resin into the root canal, and the teeth were then embedded in epoxy resin (Quick 5; Konishi, Tokyo, Japan) and randomly divided into three groups of 10 specimens each.

Torque and load measurements

The device for measuring torque and vertical load has been described previously (Kobayashi *et al.* 2002). The setup is shown in Figs 1 and 2. A load cell A (FGC-1; Shimpo, Tokyo, Japan) with capacity for 9.8 N was used for recording the torque, and a load cell B (FGC-5; Shimpo) with capacity for 49.03 N for recording the vertical load applied to the tooth. The tooth was set on a rotation stage, which was fixed on the B-load cell. The rotation stage had a cantilever to push the A-load cell when the tooth rotated. The torque (N mm) applied to the file was defined as r (radius of the cantilever, in mm) times the load (N) generated at the A-load cell. The outputs of both load cells were connected to a digital oscilloscope (Omniace RT 3600; Sanei-NEC, Tokyo, Japan), which recorded the amplitudes of the torque and vertical load in real time. The oscilloscope also calculated the area surrounded by the curve of the torque and base line. Dividing this area (A) by the working time (t, in seconds), the average torque was obtained using the following formula:

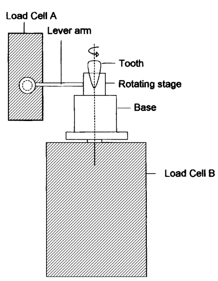

Figure 1 Front view of measuring device.

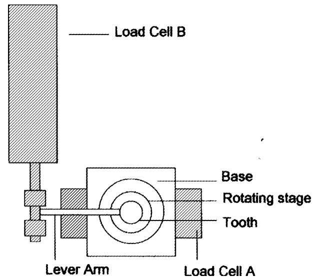

Figure 2 Top view of measuring device.

$$\text{Average torque (g cm)} = 3A/100t,$$

where 3 is the radius of the cantilever in cm and 100 is the sampling frequency per second. The values (g cm) obtained were later converted to SI unit (N mm).

Average load was also calculated in the same way. The accuracy of the load cells was checked by loading them with a calibrated weight. Both the load cells were zeroed before each root canal was instrumented.

Root canal instrumentation method

In this study, RaCe .02 taper Step Back 720 Ni-Ti files were used in group 1, RaCe .04 taper Step Back 721 Ni-Ti files in group 2 and Profile .04 Ni-Ti files (Dentsply Tulsa Dental, Tulsa, OK, USA) and Orifice Shapers (Dentsply Tulsa Dental) in group 3. All instruments were used with the Tri Auto ZX (J. Morita Co., Tokyo, Japan) automatic handpiece at a speed of 300 rpm in manual mode, in which there is no torque-reverse function.

In each experimental group, root canal preparation was carried out using a set of five individual instruments (Table 1), and each set was used a maximum of

Table 1 File sequences, sizes and tapers of three experimental groups

	Sequence				
	First	Second	Third	Fourth	Fifth
Group 1 (RaCe 720)	30/0.06	25/0.02	30/0.02	35/0.02	40/0.02
Group 2 (RaCe 721)	30/0.06	40/0.06	25/0.04	30/0.04	35/0.04
Group 3 (ProFiles)	30/0.06	40/0.06	25/0.04	30/0.04	35/0.04

eight times. According to the manufacturer, the use of an RaCe instrument in a straight canal is considered to be safe up to eight times. Each canal was instrumented with a slight in-and-out file movement of 1–2 mm until the working length was reached. The canal was irrigated with distilled water between each file exchange.

The effects of instrument technique and sequence on torque and vertical load were analysed by one-way analyses of variance (ANOVA) and Tukey's *post-hoc* test. Statistical significance was determined at the 95% confidence level.

Results

Torque

Significant differences between groups 1 and 3, and between groups 2 and 3 were found ($P < 0.0001$), and average torque was higher in group 3 in both cases (Table 2, Fig. 3). There was no significant difference between groups 1 and 2.

The average torque exerted with the first file was high in all groups, but the average highest torque recorded was obtained with the second file of group 3 (5.99 N mm). Lowest one obtained was with the third file of group 1 (3.2 N mm).

Vertical load

Average vertical load varied more than torque (Table 2, Fig. 4). Higher values were recorded with the first file in all groups. The highest average vertical load recorded was obtained with the fifth file of group 3 (2.01 N). Significant differences were found between groups 1 and 3, and between groups 2 and 3 ($P < 0.0001$). The values of vertical load were the highest for group 3 followed by group 2.

Discussion

Results of a number of studies have shown a correlation between torsional or vertical forces and the incidence of instrument fractures under clinical conditions (Sattapan *et al.* 2000, Peters & Barbakow 2002).

The results of the current study showed that the torque generated during instrumentation followed a similar pattern in all groups. However, the values obtained with RaCe files were significantly lower than those generated with ProFiles.

The first instrument produced a high torque in all groups, and this was expected since it had a large diameter and functioned as an orifice opener. In groups 2 and 3, two instruments functioned as orifice openers (first and second instruments), whilst in group 1 this function was fulfilled by only one instrument (first file). In group 1, there was a decrease in torque values subsequent to the use of the first instrument, because the second one had a considerably smaller taper and smaller tip size. In group 3, a small increase in torque following the use of the first instrument was observed.

Analysis of the average torque exerted by individual instruments were performed between groups 2 and 3 (group 1 was not included because of the different working sequence of instruments), and significant differences between them were found with the first, second and fifth instruments. These findings corroborates the ones by Blum *et al.* (1999) that the amount of torque is determined, at least in part, by the size of contact area between the instrument and the canal walls, which in this study was determined by a large taper and large tip sizes. The first and second instruments of both groups 2 and 3 had a 0.06 taper and

Table 2 Torque and vertical load obtained (mean ± SD)

	Group1 (RaCe 720)		Group 1 (RaCe 721)		Group 3 (ProFiles)	
	Torque (N mm)	Load(N)	Torque (N mm)	Load (N)	Torque (N mm)	Load (N)
First instrument	4.49 ± 0.69	1.08 ± 0.44	4.18 ± 0.60	1.23 ± 0.65	5.19 ± 1.23	1.87 ± 0.68
Second instrument	3.26 ± 0.26	0.55 ± 0.19	4.13 ± 0.66	1.4 ± 0.68	5.99 ± 2.07	1.28 ± 0.71
Third instrument	3.20 ± 0.22	0.52 ± 0.21	3.38 ± 0.38	1.23 ± 0.67	3.37 ± 0.37	1.67 ± 0.97
Fourth instrument	3.60 ± 0.45	0.73 ± 0.22	3.48 ± 0.35	0.94 ± 0.46	3.81 ± 0.45	1.64 ± 0.76
Fifth instrument	3.33 ± 0.44	0.64 ± 0.2	3.48 ± 0.53	0.82 ± 0.49	4.74 ± 1.11	2.01 ± 0.79

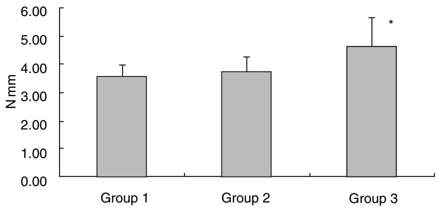

Figure 3 Mean values of torque and standard deviation obtained in all groups. *Significantly different from others (one-way ANOVA, $P < 0.0001$).

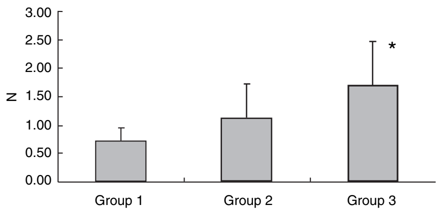

Figure 4 Mean values of vertical load and standard deviation. *Significantly different than others (one-way ANOVA, $P < 0.0001$).

30 and 40 tip size, respectively, and the fifth instrument had a 0.04 taper and 35 tip size.

During preparation with the RaCe instruments, no file deformation or fracture occurred in either group (groups 1 and 2). Deformation of one instrument was seen in group 3. It is expected that a new instrument should cut dentine walls more efficiently, and that after an instrument has been used several times, its cutting efficiency should decrease. In this study, such feature was not tested, and only by simple observation from the operator it would be difficult to assert from what moment on the instrument started to cut less effectively. Taking into consideration different surfaces of dentin and shapes of root canals, the cutting efficiency should be further studied.

The torque values found in three groups ranged from 3.2 to 5.99 N mm, and these values were within the torque range found by Sattapan *et al.* (2000) using Quantec files, and by Peters & Barbakow (2002) using Profiles .04, but slightly higher than the findings of Peters *et al.* (2003) using ProTaper files.

Apical loads recorded with RaCe instruments were significantly lower than that obtained with .04 ProFile instruments. The highest average vertical load recorded was 1.4 and 2.01 N, respectively. However, in general, the values were relatively low (<2.1 N) and this may be due to the technique employed during preparation, and, in case of RaCe instruments, the design of the blades. The average vertical loads recorded in the present study were within the range found by Sattapan *et al.* (2000) or even lower (Blum *et al.* 1999, Peters & Barbakow 2002).

Despite higher values of the average vertical load found in group 3 compared with groups 1 and 2, only one ProFile instrument deformation was observed (30/.04). No separations occurred throughout the canal instrumentation in all groups.

The current study is the first to report on the generated torque of RaCe rotary instruments in straight canals. Further investigation should be carried out on the forces developed in curved canals.

Conclusions

Torque obtained with RaCe instruments was lower than that obtained with Profiles when the step-back technique was employed. The average torque did not exceed 4.49 N mm with RaCe instruments and reached 5.99 N mm with 0.4 taper ProFile. The average vertical load recorded with RaCe files was also lower than that recorded with ProFiles. This suggests that RaCe rotary instruments might be used safely in clinical procedures with the step-back technique.

References

Barbakow F, Lutz F (1997) The Lightspeed preparation technique evaluated by Swiss clinicians, after attending continuing education courses. *International Endodontic Journal* **30**, 46–50.

Blum JY, Cohen A, Machtou P, Micallef JP (1999) Analysis of forces developed during mechanical preparation of extracted teeth using Profile NiTi rotary instruments. *International Endodontic Journal* **32**, 24–31.

Bryant S, Thompson S, Al-Omari M, Dummer PMH (1998) Shaping ability of Profile rotary nickel-titanium instruments with ISO sized tips in simulated root canals: Part 1. *International Endodontic Journal* **31**, 275–81.

Gambarini G (2001a) Advantages and disadvantages of new torque-controlled endodontic motors and low-torque Ni-Ti rotary instrumentation. *Australian Endodontic Journal: the Journal of the Australian Society of Endodontology* **27**, 99–104.

Gambarini G (2001b) Cyclic fatigue of ProFile rotary instruments after prolonged clinical use. *International Endodontic Journal* **34**, 386–89.

Glosson CR, Haller RH, Dove SB, del Rio CE (1995) A comparison of root canal preparations using Ni-Ti hand, Ni-Ti engine-driven and K-Flex endodontics instruments. *Journal of Endodontics* **21**, 146–51.

Kobayashi C, Yoshioka T, Suda H (1997) A new engine-driven canal preparation system with electronic canal measuring capability. *Journal of Endodontics* **23**, 751–4.

Kobayashi C, Yoshioka T, Murate-Oishi A et al. (2002) Dynamic observation of the stress applied to a file during root canal preparation. Part 1. Manual instrumentation. *The Japanese Journal of Conservative Dentistry* **45**, 1044–8.

Mandel E, Adib-Yazdi M, Benhmou LM, Lachkar T, Mesgouez C, Sobel M (1999) Rotary Ni-Ti profile systems for preparing curved canals in resin blocks: influence of operator on instrument breakage. *International Endodontic Journal* **32**, 436–43.

Peters OA, Barbakow F (2002) Dynamic torque and apical forces of ProFile .04 rotary instruments during preparation of curved canals. *International Endodontic Journal* **35**, 379–89.

Peters OA, Peters CI, Schönenberger K, Barbakow F (2003) Pro Taper rotary root canal preparations: assessment of torque and force in relation to canal anatomy. *International Endodontic Journal* **36**, 93–9.

Pruett J, Clement D, Carnes DJ (1997) Cyclic fatigue testing of nickel-titanium endodontics instruments. *Journal of Endodontics* **23**, 77–85.

Sattapan B, Palamara JEA, Messer HH (2000) Torque during canal instrumentation using rotary nickel-titanium files. *Journal of Endodontics* **26**, 156–60.

Schäfer E (1997) Root canal instruments for manual use: a review. *Endodontics and Dental Traumatology* **13**, 51–64.

Thompson SA, Dummer PMH (1997) Shaping ability of ProFile.04 Taper Series 29 rotary nickel-titanium instruments in simulated root canals. Part 1. *International Endodontic Journal* **30**, 1–7.

Yared GM, Bou Dagher FE, Machtou P (2000) Cyclic fatigue of ProFile rotary instruments after clinical use. *International Endodontic Journal* **33**, 204–7.